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COMPUTED TOMOGRAPHY APPARATUS COMPRISING A FADE-IN DEVICE AT THE EMITTER END, AND METHOD FOR OPERATING SUCH A COMPUTED TOMOGRAPHY APPARATUS

The invention concerns a computer tomography apparatus with an x-ray radiator rotatable around a system axis, with an x-ray detector and with a radiator-side gating device that comprises two opposite absorber elements that can be adjusted in a straight line, in particular that can be adjusted with regard to their separation from one another, for variable delimitation of the ray beam. The invention also concerns a method for operation of such a computer tomography apparatus, in which an examination subject is scanned under rotation of the x-ray radiator and by means of a translatory relative movement between the x-ray radiator and the examination subject in the direction of the system axis.

In an examination of an examination subject or a patient in an x-ray diagnostic apparatus, the examination subject is inserted into an x-ray beam emitted by an x-ray source, and the radiation attenuation resulting from this is detected by an x-ray detector. The examination subject is thus located in the beam path between the x-ray receiver and the x-ray detector. The typical x-ray tubes used as x-ray radiators radiate x-ray radiation in a significantly larger solid angle than is necessary for examination at the patient. In order to prevent an unnecessary radiation exposure at the patient, the necessity thus exists to gate out unnecessary x-rays. For this, in conventional x-ray apparatuses it is known to apply a radiator-side gating device immediately after the x-ray radiator in the beam path, which gating device is also designated as a primary beam diaphragm. For example, such a primary beam diaphragm, with diaphragm plates which can be moved opposite to one another as absorber elements, is known from EP 0 187 245 A1.

In computer tomography apparatuses with multi-row x-ray detectors, a detector-side beam diaphragm (or a beam diaphragm near to the detector) that is mounted in the beam path between the patient and the x-ray detector is also frequently used in

addition to a radiator-side gating device that is arranged in the beam path between the x-ray radiator and the patient. It is thereby possible to shade one or more detector rows of the plurality of detector rows present and to use the remaining detector rows as active detector rows. Since, in a computer tomography apparatus (in particular in such a computer tomography apparatus of the third generation), the x-ray detector rotates around the patient together with the x-ray radiator mounted on a gantry (rotating frame), the control and/or regulation device is normally curved in the azimuthal direction. In adaptation to this geometry, in particular in order to realize a constant separation, a detector-side diaphragm disclosed in DE 42 26 861 C2 for a computer tomography apparatus is fashioned with arc-shaped diaphragm plates.

With regard to the radiator-side diaphragm, the objective exists that this only passes such rays which can also actually be detected by the x-ray detector (and in particular by its active detector rows). Other x-rays would only unnecessarily penetrate the patient and unnecessarily increase the radiation exposure. Since the multi-row x-ray detector arrays in computer tomographs are normally equipped with orthogonal rows and columns of detector elements, with regard to the primary beam diaphragm the objective exists to gate an exactly rectangular ray beam. Given flat or planar diaphragm plates or absorber elements, this is not perfectly possible due to different separations of the x-rays of the ray beam, respectively measured from the focus of the x-ray radiator to the point of impact on the diaphragm plate. To prevent corresponding disadvantageous edge effects in the gating, in US 6,396,902 B2 an x-ray collimator is specified in which a plurality of slits of different but respectively constant width are introduced in a carrier or base body, whereby the carrier body is curved such that the gating slits are also curved. Via the curvature of the slits, it should be ensured that a ray beam exactly rectangular in cross section is gated on the x-ray detector.

For different examination methods, in order to be able to operate with different numbers of active detector rows or with an x-ray beam gated at different widths in

the direction of the patient axis, given the x-ray collimator known from US 6,396,902 B2 the entire bearing body produced from x-ray-absorbing material must be moved. According to the local disclosure, this occurs via rotation of the bearing body, which is why the bearing body is also curved around a second axis. In order to thereby also be able to bring another diaphragm slit into the matching position, the rotation axis would have to be located at the height of the focus of the x-ray radiator. This at best possible with very large mechanical effort.

Alternatively, the rotated bearing body would have to be readjusted into the correct position via a shifting movement, which is likewise very elaborate. Moreover, the production of a bearing body curved around two axes is likewise connected with large expenditure, whereby this must also still be produced from x-ray-absorbing material, meaning from a material with a high atomic number.

Moreover, what is disadvantageous from the x-ray collimator known from US 6,396,902 B2 is that only a finite number of slits of discrete width can be applied or, respectively, introduced on or in the bearing body.

The invention is based on the object to specify a computer tomography apparatus with a radiator-side gating device which exhibits more flexible gating possibilities and which can be simultaneously be produced with less expenditure. A method for operation of such a computer tomography apparatus should also be specified.

The object with regard to the apparatus is achieved according to the invention with regard to the computer tomography apparatus cited above in that the absorber elements exhibit a curved shape, and that the gating device comprises an adjustment device that acts on the absorber elements such that the absorber elements can be moved perpendicular to their longitudinal direction, in particular can be adjusted [displaced] relative to one another. The elements can in particular be moved in a direction parallel to the system axis. The absorber elements exhibit

the curved shape in particular on their outer contour delimiting the x-ray beam, i.e. for example on an edge forming a diaphragm slit.

The inventive computer tomography apparatus has the advantage that the slit width is continuously or freely selectable between the curved absorber elements or diaphragm jaws [cheeks], and thus the slice thickness adjustable at the computer tomography apparatus can also assume non-discrete values. Wide detector rows can also be only partially irradiated, and thus slices that are thinner than the width of the detector elements are also possible in a simple manner.

Moreover, the gating device of the inventive computer tomography apparatus requires absorber elements that are necessarily curved only in one direction or in one plane and that thus exhibit, for example, a shape as is created given bending of a plate around a straight edge (for example "banana shape"). The gating device can thus also be produced simply.

The variation, continuous to the greatest possible extent, of the slit width or the collimation width possible in the computer tomography apparatus according to the invention allows – as already mentioned – a free selection of the slice thickness and a flexible selection of the active rows of detector elements. However, a readjustment of the diaphragm setting given a change of the focus size in the x-ray receiver occurring during the operation is moreover also still possible.

According to a preferred embodiment, the absorber elements can be moved independent of one another. It is therewith in particular possible to move the absorber elements not only opposite one another, but rather also concurrently in one and the same direction. For example, a diaphragm readjustment is thereby also possible given a variation of the focus position in the diaphragm rays occurring during the operation (focal spot tracking). This means that the entire slice can also be shifted in the z-direction with a constant slice width. Moreover, a dynamic variation of the collimation width is therewith possible, whereby (for example) an

unwanted over-radiation at the beginning and at the end of a spiral scan can be reduced, in that one of the absorber elements is still closed at the beginning of the scan and is only opened at the beginning of the scan with the beginning of the translatory patient bed movement in the direction of the system axis. The same is correspondingly true in reverse for the end of the scan.

The adjustment device for each of the absorber elements comprises a separate adjustment means, whereby the adjustment means are preferably fashioned for a linear movement of the appertaining absorber element. Via such a linear movement, it is ensured in an advantageous manner that sections of the curved absorber element matching one another also still lie opposite one another after a relative movement in the direction of the system axis.

With particular advantage, the adjustment means comprise a (preferably mutual) linear guide as well as, respectively, a drive means [actuator] acting on the absorber elements.

As an alternative to this, the adjustment means respectively comprise a linear motor, for example with a corresponding respective guide.

The curvature of the absorber elements runs in particular in a plane perpendicular to the system axis. The curvature in particular exhibits the shape of a circular arc whose center point lies in the focus of the x-ray radiator. Identical distances between the focus and all ray-delimiting edge regions of the absorber elements are thereby achieved in a simple manner.

According to another advantageous embodiment, the curvature radii of the absorber elements differ from one another by a value of 0.5 % to 10 % from the interval. The following advantage results from this: in order to enable a hundred-percent closure of the diaphragm, due to finishing tolerances it is normally not sufficient that the absorber elements contact only on stop [sic]. Rather, they must

at least slightly overlap, viewed in the direction of the x-ray beam. Such an overlapping is possible in an advantageous manner without scraping given different curvature radii.

The object with regard to the method is achieved according to the invention with regard to the method cited above in that, to prevent an unnecessary radiation exposure for the examination subject, the gating device is operated with absorber elements opened to different widths with regard to a center beam of the viewing field of the x-ray detector.

It is thereby possible, in particular in an advantageous manner, to prevent an over-radiation of the patient at the beginning and at the end of a scan movement or a scan (in particular a spiral scan), in that the gating device is adjusted quasi-asymmetrically.

For example, before the beginning and/or after the end of the scan movement, in particular the relative movement, one of the absorber elements is positioned in a closed position and the other absorber element is positioned in an open position.

After the beginning of the scan movement, in particular the relative movement, the absorber element located in the closed position is preferably opened in synch with the scan movement, in particular with the relative movement.

It is likewise possible that, before the end of the scan movement (in particular the relative movement), one of the absorber elements located in the open position is closed in synchronization with the scan movement, in particular with the relative movement.

A dynamic variation of the collimation width is thus effected with the gating device.

The invention is subsequently explained in detail using three exemplary embodiments and by means of Figures 1 through 7 (schematic only in part). Thereby shown are:

Fig. 1 in partially perspective, partially block diagram representation, CT apparatus comprising a gating device according to the invention,

Fig. 2 a known gating device,

Fig. 3 the gating device of the CT apparatus of Figure 1 in a schematic representation, whereby the function of the gating device is illustrated in perspective,

Fig. 4 the gating device of Figure 3 according to a first exemplary embodiment in detail,

Fig. 5 the gating device of Figure 3 according to a second exemplary embodiment in perspective representation,

Fig. 6 the gating device of Figure 5 in a cross-section representation, and

Fig. 7 the gating device of Figure 3 according to a third exemplary embodiment in detail.

A CT apparatus of the 3rd generation is shown in Figure 1 in relevant section. Its measurement arrangement comprises an x-ray radiator 2 with a gating device 3 positioned in front of it, near the source, and an x-ray detector 5, fashioned as a laminar array of a plurality of rows and columns of detector elements (one of these is designated with 4 in Fig. 1), with an optional beam diaphragm (not explicitly shown) positioned in front of said x-ray detector 5, close to the detector. For reasons of clarity, in Figure 1 only 4 rows of detector elements 4 are shown;

however, the x-ray detector 5 can comprise further rows of detector elements 4, optionally also with different widths b.

The x-ray radiator 2 with the gating device 3 on the one side and the x-ray detector 5 with its beam diaphragm on the other side are mounted opposite one another on a rotary frame (gantry) (not explicitly shown), such that a pyramidal x-ray beam emitted by the x-ray radiator 2 in the operation of the CT apparatus 1 and gated by the adjustable gating device 3 (the ray beams of which x-ray beam are designated with 8) impinges on the x-ray detector 5. By means of the gating device 3 and, if applicable, by means of the detector-proximal beam diaphragm, a cross-section of the x-ray beam is thereby adjusted such that only that region of the x-ray detector 5 is uncovered that can be directly met by the x-ray beam. In the operating mode illustrated in Figure 1, this [sic] are four rows of detector elements that are designated as active rows. If applicable, further existing rows are covered by the detector-proximal beam diaphragm and are therefore not active. The gating device 3 thereby primarily amounts to the importance [sic] of preventing an unnecessary radiation exposure of the examination subject, in particular a patient, in that rays that otherwise do not arrive at the active rows are also kept away from the examination subject or patient.

The rotary frame can be displaced in rotation around a system axis Z by means of a drive device (not shown). The system axis Z runs parallel to the z-axis of a spatial rectangular coordinate system shown in Fig. 1.

The columns of the x-ray detector 5 likewise run in the direction of the z-axis, while the rows (whose width b is measured in the direction of the z-axis and is, for example, 1 mm) run transverse to the system axis Z or, respectively, the z-axis.

In order to be able to bring the examination subject, for example the patient, into the beam path of the x-ray beam, a bearing device 9 is provided that can be shifted parallel to the system axis Z, thus in the direction of the z-axis, and in fact such

that a synchronization exists between the rotation movement of the rotary frame and the translation movement of the bearing device 9 in the sense that the ratio of translation speed to rotation speed is constant, whereby this ratio is adjustable in that a desired value selected for the infeed h of the bearing device 9 per rotation of the rotary frame.

A volume of an examination subject located on the bearing device 9 can thus be examined in the course of a volume scanning, whereby the volume scanning is effected in the form of a spiral scanning in the sense that, under rotation of the rotary frame and simultaneous translation of the bearing device 9 per rotation of the rotary frame, a plurality of projections is acquired from various projection directions. Given the spiral scanning, the focus F of the x-ray radiator 2 moves on a spiral track S relatively to the bearing device 9. A sequence scan is also possible as an alternative to this spiral scan.

The measurement data, read out in parallel during the spiral scan from the detector elements of each active row of the detector system 5 and corresponding to the individual projections, are subjected to a digital-analog conversion in a data processing unit 10, serialized and transferred to an image computer 11 which shows the result of an image reconstruction on a display unit 16, for example a video monitor.

The x-ray radiator 2, for example an x-ray tube, is supplied with the necessary voltages and currents by a generator unit 17 (optionally likewise mutually rotating). In order to be able to adjust this to the respectively necessary values, a control unit 18 with keyboard 19 that allows the necessary adjustments is associated with the generator unit 17.

The other operation and control of the CT apparatus 1 also ensues by means of the control unit 18 and the keyboard 19, which is illustrated in that the control unit 18 is connected with the image computer 11.

Among other things, the number of the active rows of detector elements 4 (and therewith the position the gating device 3 and of the optional detector-proximal beam diaphragm) can be adjusted, for which the control unit 18 is connected with adjustment units 20 or, respectively, 21 associated with the gating device 3 and the optional detector-proximal beam diaphragm. Furthermore the rotation time that the rotary frame requires for a complete rotation can be adjusted, which is illustrated in that a drive unit 22 associated with the rotary frame is connected with the control unit 18.

In Figure 2, it is shown which gating results given a known gating device 3A with two separate absorber elements 30A, 31A. Shown is an x-ray beam with edge rays 8A which emanates from a focus F of an x-ray radiator 2A.

Both edge rays 8A emanating from the focus F and passing the (in this Figure) rear absorber element 30A respectively cover a distance d_2 from the absorber element 30A. In contrast to this, the comparable distance d_1 in the indicated central ray 36 is less than in the edge rays 8A. This is correspondingly true for the edge rays on the opposite side of the slit 32A. The result is that an x-ray beam whose outer contour 34A is not rectangular is gated on the x-ray detector 5A with its individual detector elements 4A in cross-section. In order to fully illuminate all detector elements 4A of the detector row (with its width b) illuminated here, the outer contour 34A must be set such that its width B_2 at the edge approximately corresponds to the width b of the detector row. As a result of the different distances $d_1 \neq d_2$, a larger width B_1 of the outer contour 34A of the x-ray beam then results in the middle of the detector row. The portion of the x-ray beam occurring in this barrel-shaped region (here shown exaggerated, but nevertheless disturbing with regard to the radiation dose) is ultimately not used.

The gating device 3 of the CT apparatus 1 according to the invention according to Figure 1 is illustrated in Figure 3 in schematic representation and perspective view.

The gating device 3 comprises two curved absorber elements 30, 31, between which a slit 32 is formed that can pass the x-rays emanating from the focus F of the x-ray radiator 2. The absorber elements 30, 31 (produced from heavy metal, for example from tungsten and/or from tantalum) are curved in a circular arc, whereby the middle point of the circular arc lies in the focus F of the x-ray radiator 2. It is thereby ensured that the separation, both of the edge rays 8 and of a central ray 36 respectively measured from the focus F to the absorber elements 30 (or 31), respectively exhibits the same value d. In an advantageous manner, it is thereby achieved that the x-ray beam gated on the x-ray detector 5 exhibits in cross-section a rectangular outer contour 34 whose constant width B can be perfectly adapted to the width b of one or more detector rows.

Both absorber elements 30, 31 can be moved or driven independent of one another, in particular also running in parallel or opposite, which is indicated by corresponding double arrows 40, 41 in Figure 3.

In Figure 4, it is shown how the gating device 3 shown only schematically in the Figure can be accommodated in a common housing 50, together with a filter device 45 with one or more (copper) spectral filters 46 (with drive element 47 belonging to the filter changer) and with a wedge filter 48 serving for the variable attenuation of the x-ray beam. The housing 50 comprises an entrance opening 51 on the side of the focus F and an exit opening 52 on the opposite side.

Moreover, in Figure 4 it is shown that a separate adjustment means 60 or 61 is present for each of the absorber elements 30, 31, with which adjustment means 60 or, respectively, 61 the absorber elements 30, 31 can be moved linearly, independent of one another. In the exemplary embodiment of Figure 4, the first adjustment means 60 for one of the absorber elements 30 comprises a first drive means 62 fashioned as a step motor, which drive means 62 acts on one of the absorber elements 30 via a first gear 63 and via a first toothed belt 64. For the other absorber element (31, not visible in Figure 4), a second drive means 67

(likewise fashioned as a step motor) and a second gear 68 is [sic] correspondingly present in the second adjustment means 61. Both drive means 62, 67 act (for example via different spindle guides) on the two absorber elements 30, 31 moving linearly in the z-direction on one and the same linear guide 65.

The gating device 3 according to Figure 3 is reproduced in Figure 5 in a perspective representation according to a second exemplary embodiment. The special banana-like shape of the diaphragm backs 30, 31 is better visible in Figure 5. Moreover, it results from Figure 5 that the common linear guide 65 can comprise a left-side first track 65A as well as a right-side second track 65B.

The gating device 3 of Figure 5 is explained again in Figure 6 in a cross-section representation in the z-direction. Therein it is in particular visible that the absorber elements 30, 31 are slightly displaced relative to one another in the height direction y, essentially corresponding to the direction of the radiated x-ray beam, in order to prevent a passage of x-ray radiation (conditional upon finishing tolerances) given a complete closing of the gating device 3.

In order to be able to execute the overlap of the absorber elements 30, 31 without friction, it is advantageous that the curvature radii of the absorber elements are slightly different. For example, these are 197 mm or, respectively, 200 mm.

A third exemplary embodiment of the gating device according to Figure 3 is shown in detail in Figure 7. This exemplary embodiment is essentially identical to the exemplary embodiment according to Figure 5, however differs from this in that both adjustment means 60, 61 for the absorber elements 30 or, respectively, 31 comprise a first linear motor 71 with guide and a second linear motor 72, likewise with corresponding guide.

Instead of a linear guide, other linear adjustment possibilities can also be used.

With the gating device 3, in connection with a focus-phi-z regulation it is possible to correspondingly readjust a variation of the focus position or focus size in the x-ray radiator 2 with regard to the diaphragm adjustment.